Electro-Thermo-Mechanical Modeling in FLOORS

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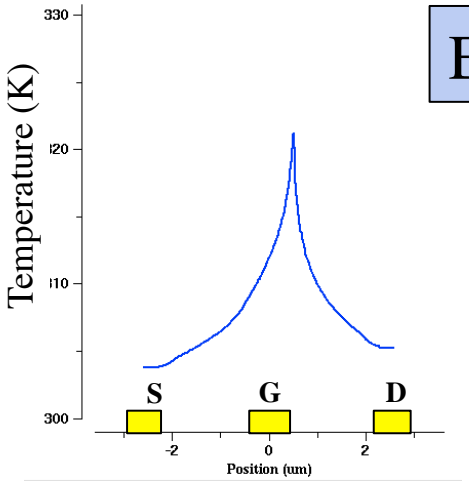
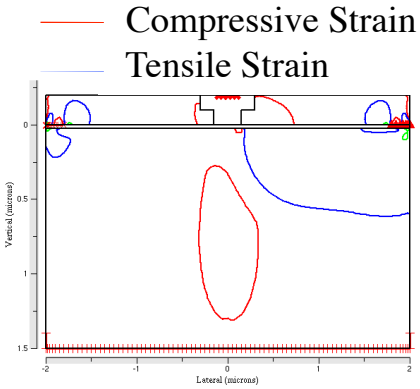
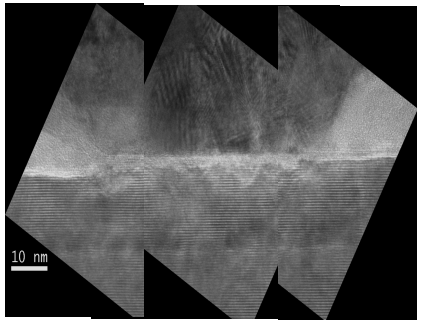
FLOORS

Electro-Thermo-Mechanical Modeling





Defect Modeling → Device Performance Prediction



t=0, As Built

t>0, Degradation

Electro-Thermo-Mechanical Simulation

Poisson's Eq.

Electrical: $\nabla^2 \Psi = -\frac{q}{\varepsilon}(p - n)$

Electron/Hole Continuity Eq.

$$\frac{dn}{dt} = \frac{1}{q}\nabla J_n$$

$$J_n = -q\mu_n n \nabla \phi_n$$

Heat Conduction Eq.

Thermal: $c\frac{\partial T}{\partial t} - \nabla \cdot K \nabla T = Q$ where, $Q = J_n^2 \frac{1}{q\mu_n n}$

Equilibrium Eq.

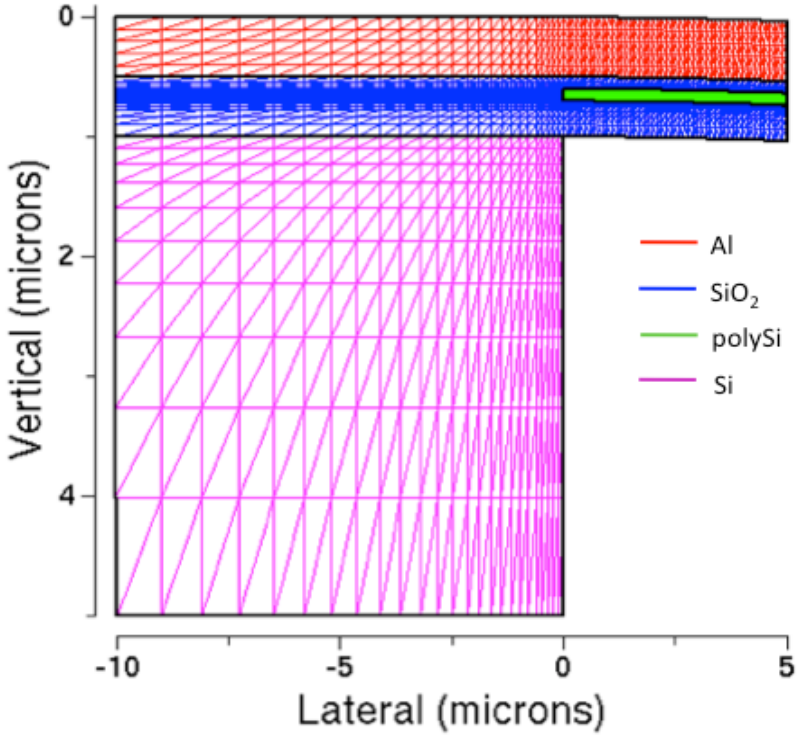
Mechanical: $\nabla \cdot \sigma + F = 0$ where, $\sigma = D\,(\epsilon - \epsilon_0)$ $D(T)$

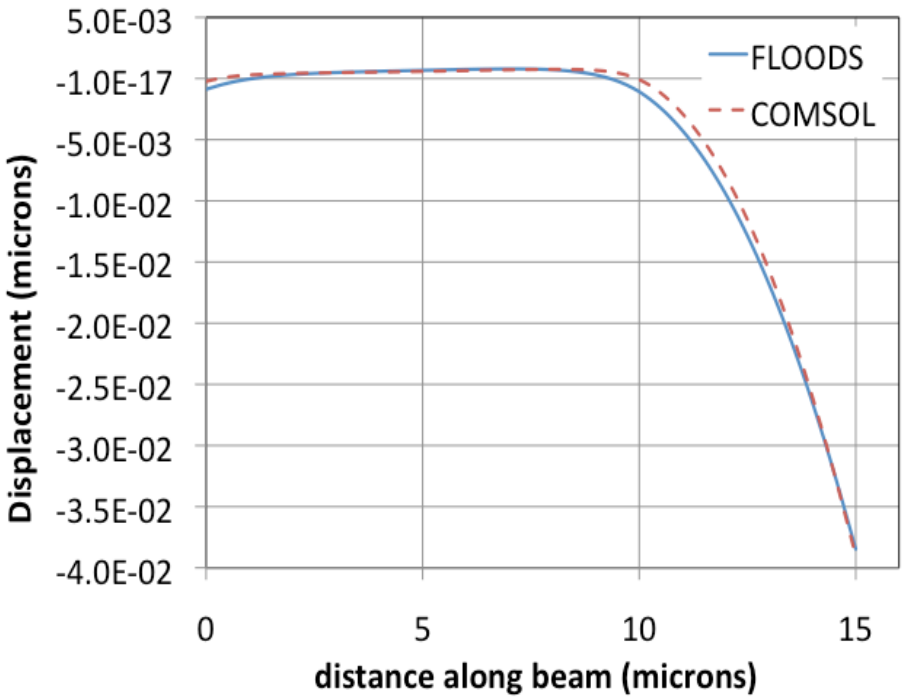
$$\epsilon_0 = \nabla \Psi \cdot d_{pz}$$

$$\epsilon_0 = \alpha_{mismatch} \Delta T$$

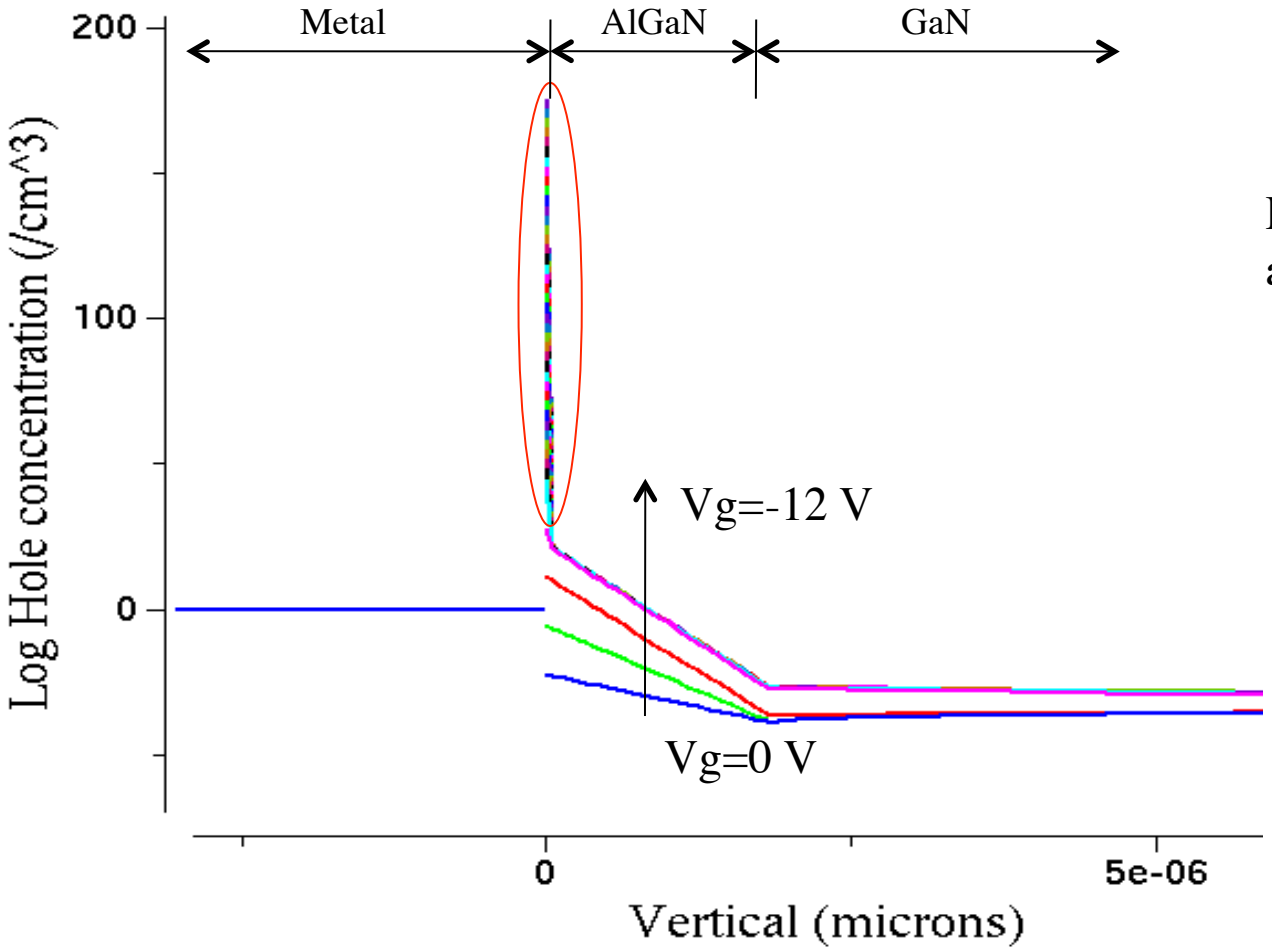
ETM Simulation Validation with COMSOL

2-D MEMS thermal actuator with 3V bias across the polySilicon heater





FLOORS Convergence Issues



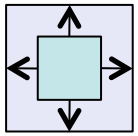
Nonconvergence after Vg=-12 V (Vds=0 V)

Hole conc. ≈ 1e190/cm^3 at Metal/AlGaN interface

Solution: Add physics for gate leakage mechanism to provide a boundary condition.

FLOORS Capability: ETM Simulation

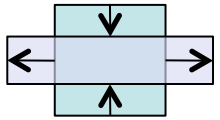
Isotropic Thermal Expansion



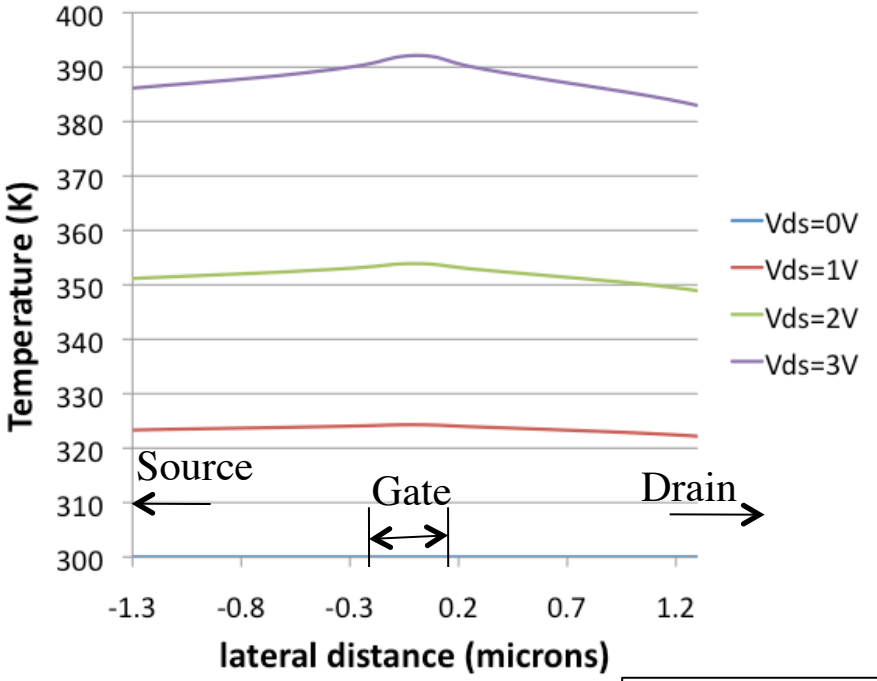
$$\epsilon_0 = \alpha_{mismatch} \Delta T$$

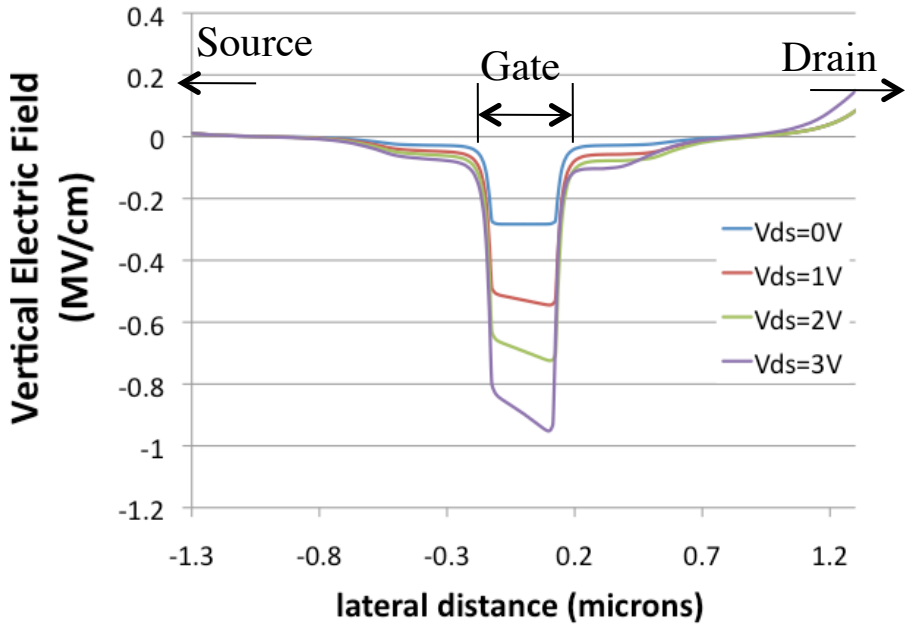
$$\sigma = D\,(\epsilon - \epsilon_0)$$
$$D(T)$$

Inverse Piezoelectric Effect



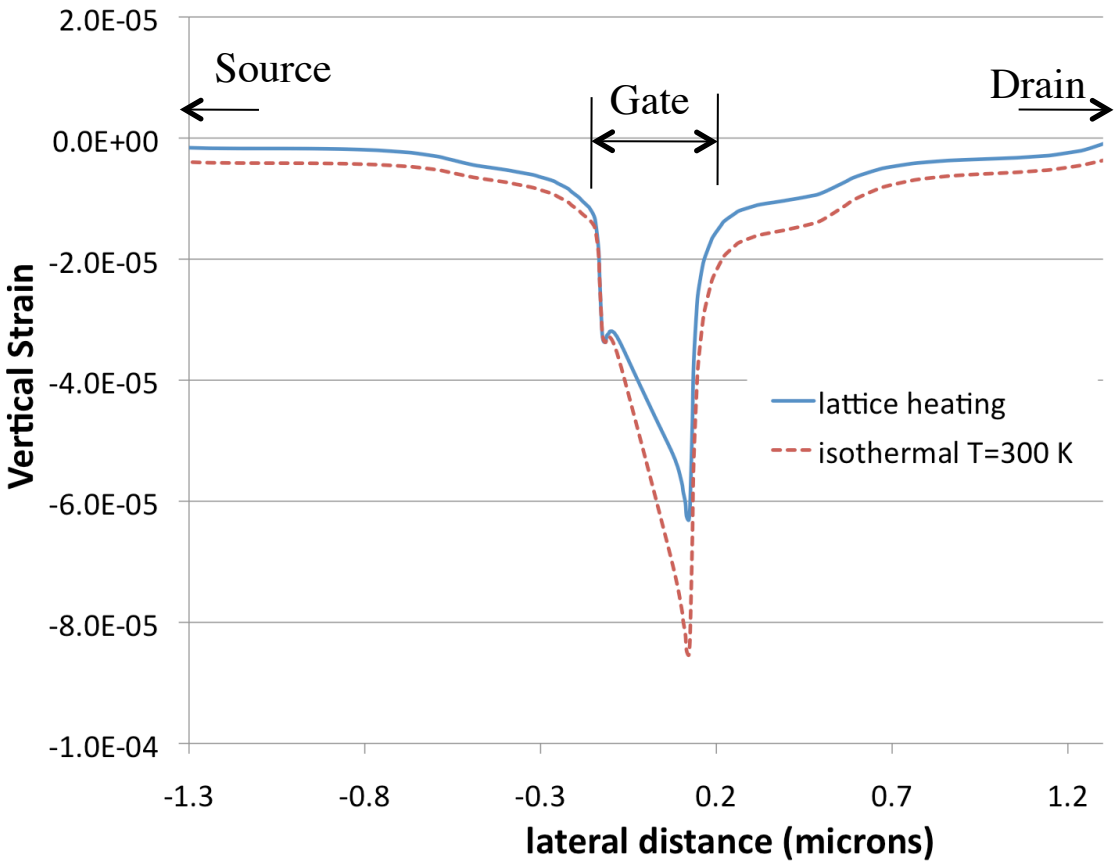
$$\epsilon_0 = \nabla \Psi \cdot d_{pz}$$





Slice taken 15nm below AlGaN surface

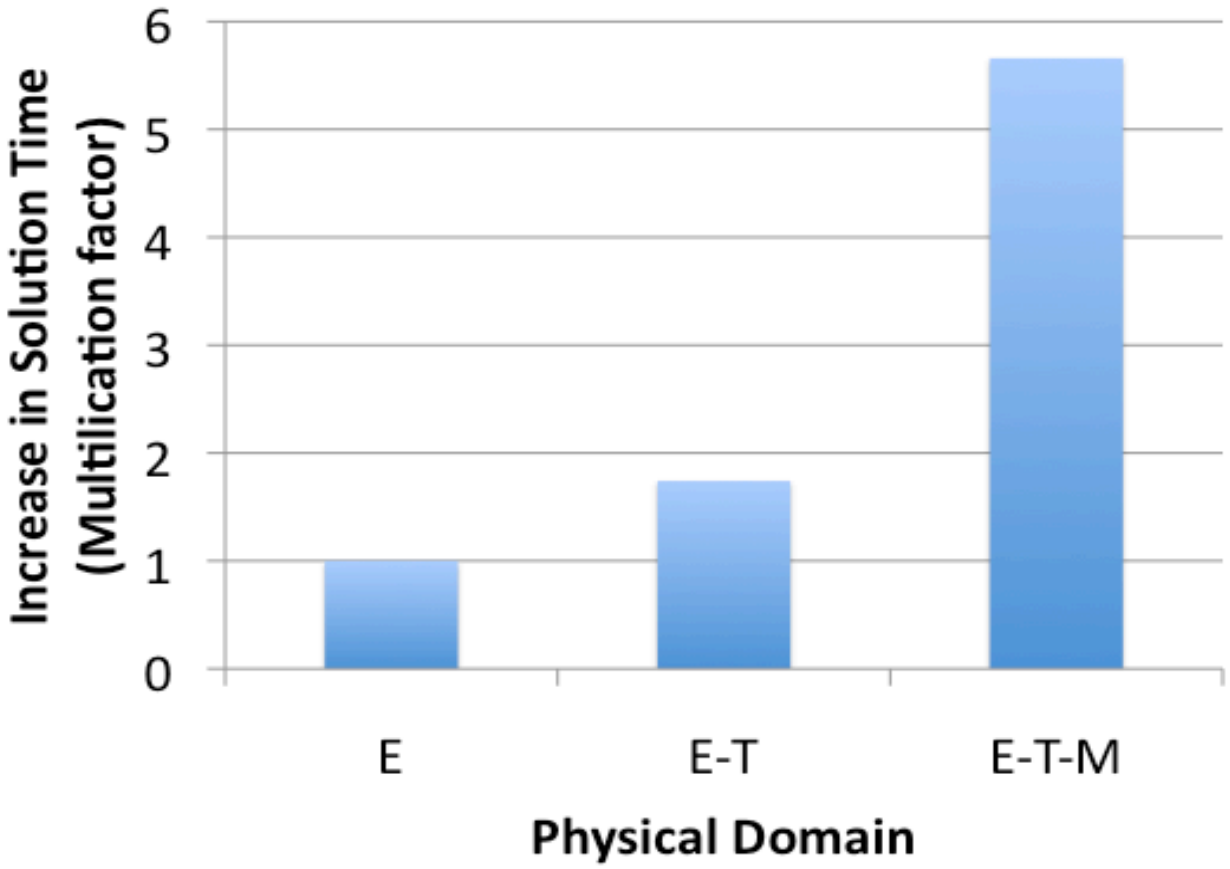
FLOORS Capability: ETM Simulation



Vgs=0.0 V
Vds=3.0 V

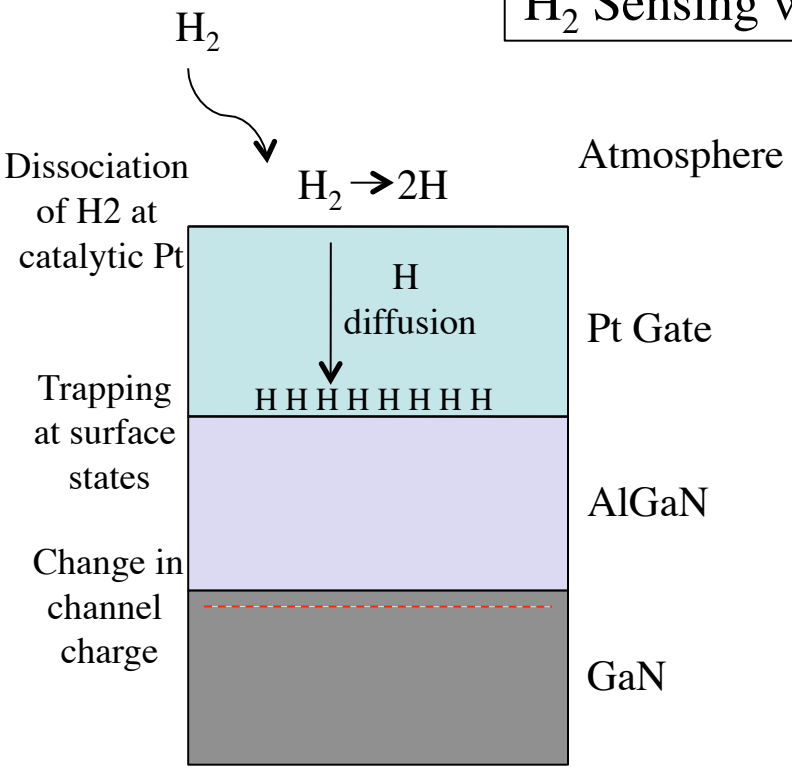
Reduction in compressive strain due to:
1) thermal expansion
2) decrease in Young's modulus with increasing temperature

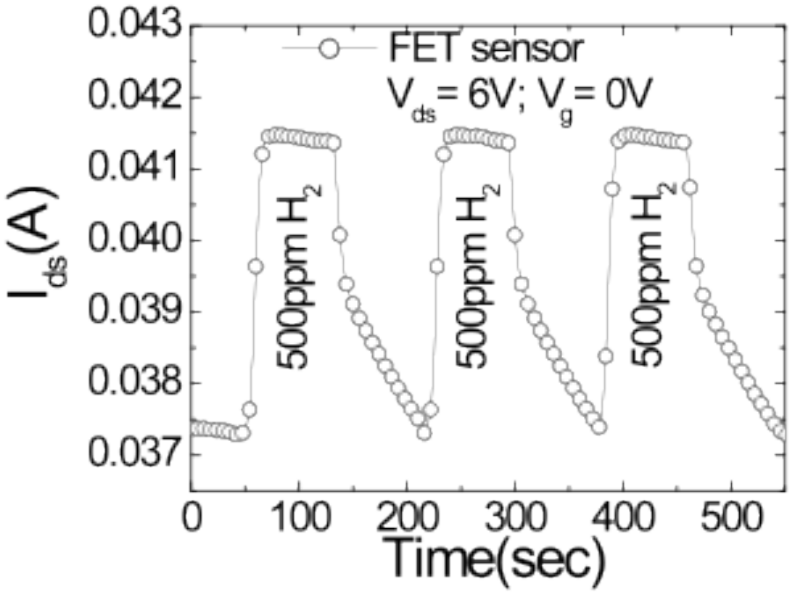
FLOORS Capability: ETM Simulation



Other Capabilities: AlGaN/GaN ChemFET

H_2 Sensing with AlGaN/GaN HEMT





Wang et. al.. Appl. Phys. Lett. 87, 172105 (2005)

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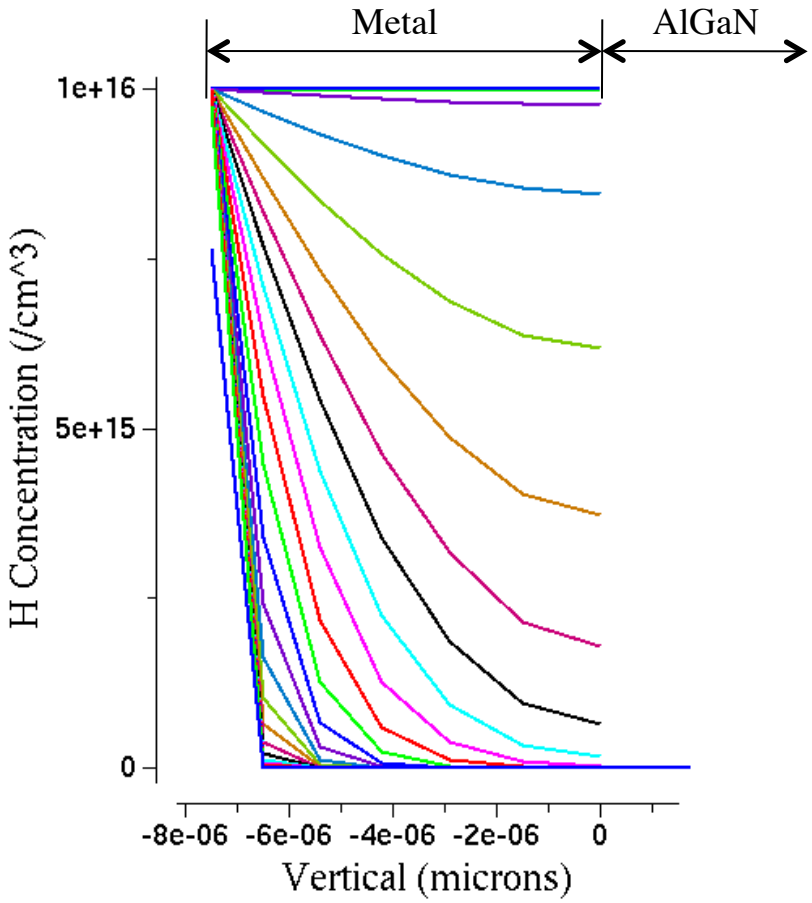
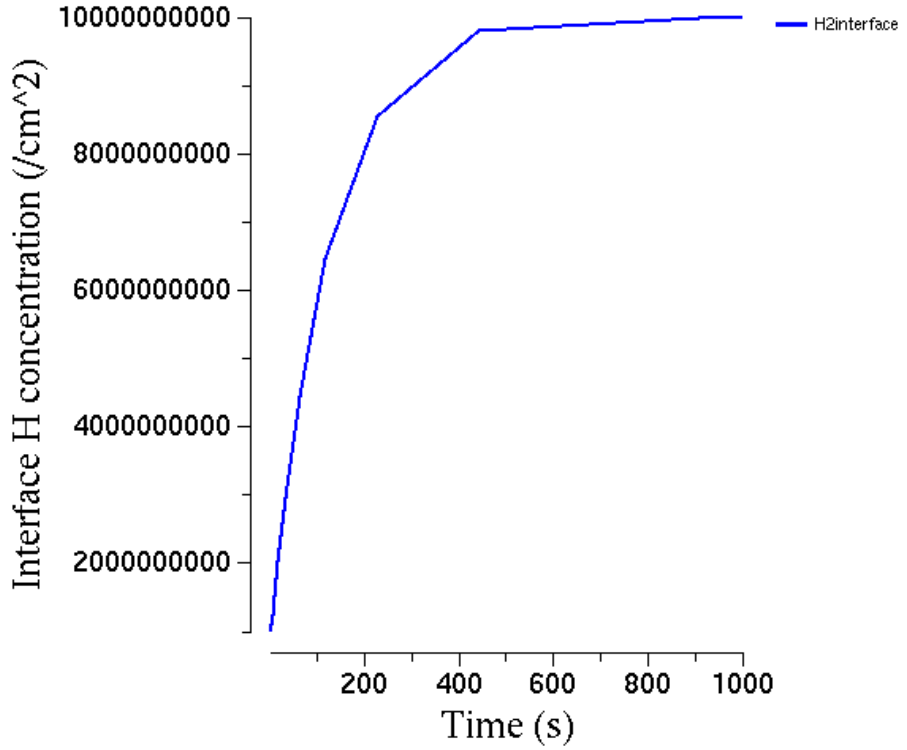


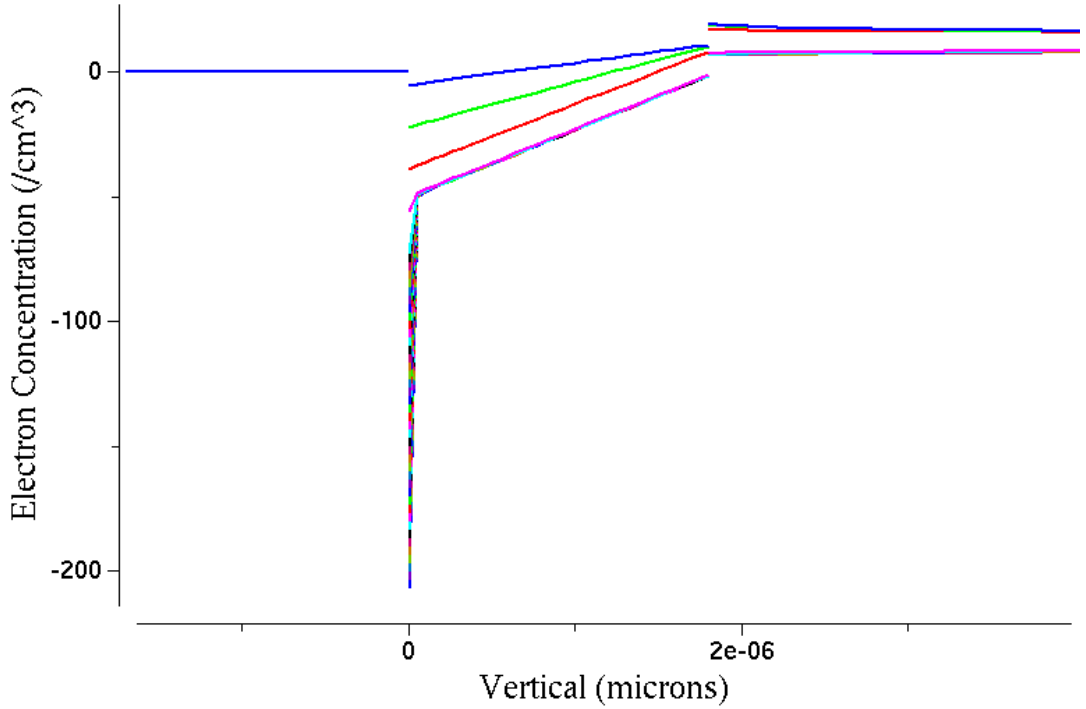


H concentration saturates at
Trap capacity = 1.0e10/cm^2

Summary and Future Work

- FLOORS provides fully-coupled ETM simulation capabilities
  - Unique in that mechanical-induced electrical changes may be simulated
  - Validation with COMSOL
  - Convergence issues exist at high negative gate bias

- Future Work
  - Incorporate Poole-Frenkle emission as gate leakage model for bias conditions near the threshold voltage.


Electron Concentration (/cm^3)
0
-100
-200
0
2e-06
Vertical (microns)